

THE EFFECT OF MOUNTAIN BARRIERS IN THE PATH OF METEOR
PROPAGATION OF RADIO WAVES

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ABSTRACT. The effect of mountains in the propagation path on the propagation of radio waves by meteors is discussed. The results are compared with propagation paths across plains.

The question of the effect mountains in the path of radio wave propagation have on meteor propagation has not yet been considered. /81

As is known, the propagation of radio waves over radio paths through meteor trails is possible if the radio waves are properly oriented and are in a region in which meteor radio propagation is possible. This region, which from now on will be called the permissible region, after K. V. Kostylev, is a part of the meteor zone of the ionosphere, and is simultaneously visible from both ends of the path.

Mountains in the path of radio wave propagation reduce the permissible region, causing primarily a change in the values of such fundamental characteristics of meteor radio propagation as the number of meteor reflections and the duty cycle in the coupling line. However, this article will not consider these effects, nor will it consider the features associated with diffraction and interference from possible reflections of radio waves from mountains.

We will examine only the magnitude of the change in the permissible region of four arbitrarily chosen paths over mountainous terrain (Table 1, columns 2-5), characteristic of which is the fact that the end points of the path, T and R, rise to some heights h_T and h_R above the surface of the terrestrial spheroid, and that there are mountains near these points along the radio wave propagation path.

Let us call the paths, the end points of which are on the surface of the terrestrial spheroid, the "plain" paths, and those with mountains in the radio wave propagation path "mountain" paths.

If T^* and R^* designate the transmission and reception points of a plain path, and T and R the points of a mountain path at heights h_T and h_R above the terrestrial spheroid, then the apparent horizon lines H_T /82

and H_R , for points T and R descend below the horizon lines H_{T^*} and H_{R^*} for the points T^* and R^* .

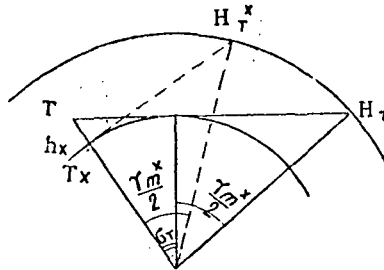


Figure 1. Geometry of the position of points on the apparent and true horizons points H_T and H_{T^*} for points T and T^* for mountain and plain paths, respectively.

From Figure 1 we obtain

$$\frac{\gamma_m^*}{2} < \frac{\gamma_m^*}{2} + \sigma_n = \gamma_{mn}, \quad (1)$$

where

$$\cos \sigma_n = \frac{R}{R + h_n}, \quad (2)$$

$n = T, R.$

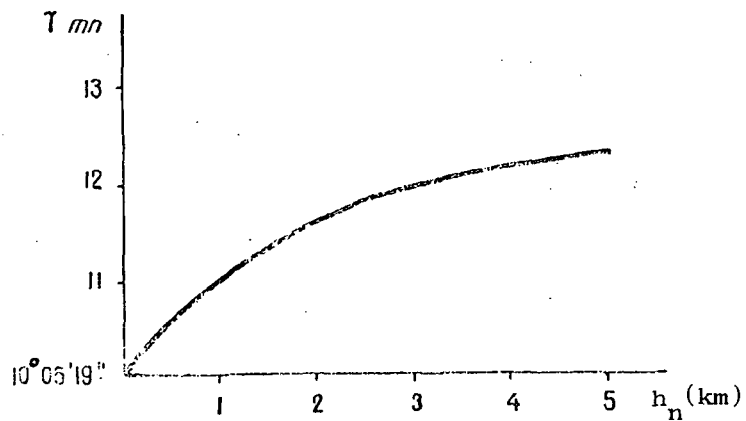


Figure 2. The angle γ_{mn} in terms of the height of the end point of a mountain meteor path.

TABLE I

Path No.	Length of path, γ , in degrees	Length of path, $2L$, in km	point	h_n	S , mountain path relative units	S^* , plain path relative units	$\frac{S - S^*}{S^*}$, %	Limit of path, γ_m , in degrees	Extended limit of path, %	Extended limit of path, km	S_{shadow} , relative units	$\frac{S_{\text{shadow}}}{S}$, %
1	1°54'4"	213	T	0.68	3.46	2.81	23	22°18'08"	10.5	235.4	1.92	56
			R	1.62								
2	6°18'0"	700	T	0.68	2.36	1.92	23	21°52'18"	8.4	188.3	1.38	58
			R	A.72								
3	8°03'2"	895	T	0.72	1.93	1.60	21	21°32'18"	6.7	150.2	0.79	41
			R	0.24								
4	12°58'4"	1440	T	0.68	1.00	0.76	32	21°30'38"	6.6	148.0	0.36	36
			R	0.24								

Figure 2 shows angle γ_{mn} in terms of height, h_n . The value of angle γ_{mn} is taken from $\gamma_m^*/2 = 10^\circ 05' 19''$ (for earth radius $R = 6367.6$ km) for $h_n = 0$ to γ_{mn} corresponding to $h_n = 5$ km.

Thus, what follows from Figures 1 and 2 and Eqs. (1) and (2) is that there will be a marked increase in the permissible region because of the rise in heights of the end points of the mountain path, or of one of the points. The degree of this increase can be found by constructing stereographic projections of the permissible regions of the T^*R^* and TR paths, using the method described in reference [1], and then comparing their areas.

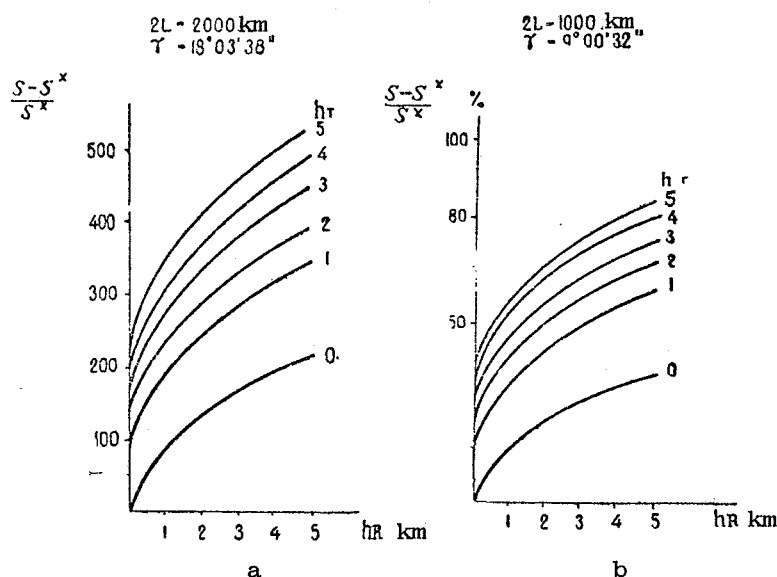


Figure 3. a, b: Relative increase in the area of the permissible region in terms of elevation of path end point.

Areas S^* and S of the permissible regions of paths T^*R^* and TR were measured in relative units (Table 1, columns 6, 7, and 8). There is no definite behavior pattern for change in relative increase in the permissible region, $(S - S^*)/S^*$, with h_T , h_R , and γ , because the calculation was made for paths of different lengths. This pattern was ascertained by establishing the relationship between $(S - S^*)/S^*$ and h_n when $\gamma = \text{constant}$, for $\gamma = 9^\circ 00' 32''$ (1000 km), $18^\circ 03' 38''$ (2000 km), and $h_n = 0-5$ km. Figure 3, a and b, shows the results.

These figures make it evident that the relative increase in the area of the permissible region increases with elongation of the path and with

rise in one, or both path and points, when paths are of different lengths. The rate of increase is higher for paths near the limiting plain path and, for a constant path length, for rise in points T and R from 0 to 1 km. Rise in both path points to a height of 5 km results in the permissible region for a 1000 km path length increasing to the permissible region of a 508.6 km plain path, and for a 2000 km path to the permissible region of a 1505.4 km path.

In the case of a plain path, angle γ_m^* determines the length (in measurement degrees) of that limiting path (≈ 2240 km), for which the permissible region becomes a point.

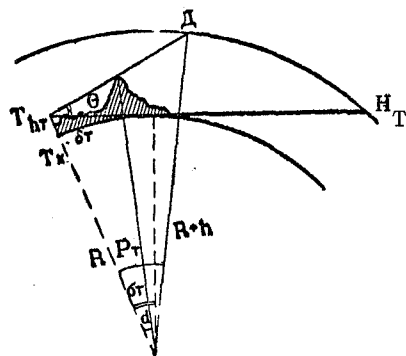


Figure 4. For the derivation of Eq. (4).

In the case of mountain paths, for which $h_T \neq 0$ and $h_R \neq 0$, the length of the limiting path (also in degrees), will be determined by the angle

$$\gamma_m = \gamma_m^* + \sigma_T + \sigma_R, \quad (3)$$

where

σ_T and σ_R are found using Eq. (2).

Consequently, when points T and R rise to some heights $h_T + h_R$, the limiting mountain path elongates to a magnitude (in degrees) of the angle $\sigma_T + \sigma_R$, and is a variable that depends on σ_T and σ_R , and therefore, on h_T and h_R (see Table 1, columns 9, 10, and 11).

To make apparent the degree of decrease in the area of the permissible region caused by the presence of mountain chains in the path of meteor

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radio propagation we plotted terrain chartlets from topographic maps for each end point of the four paths cited on azimuths of ψ_n ($n = T, R$) in

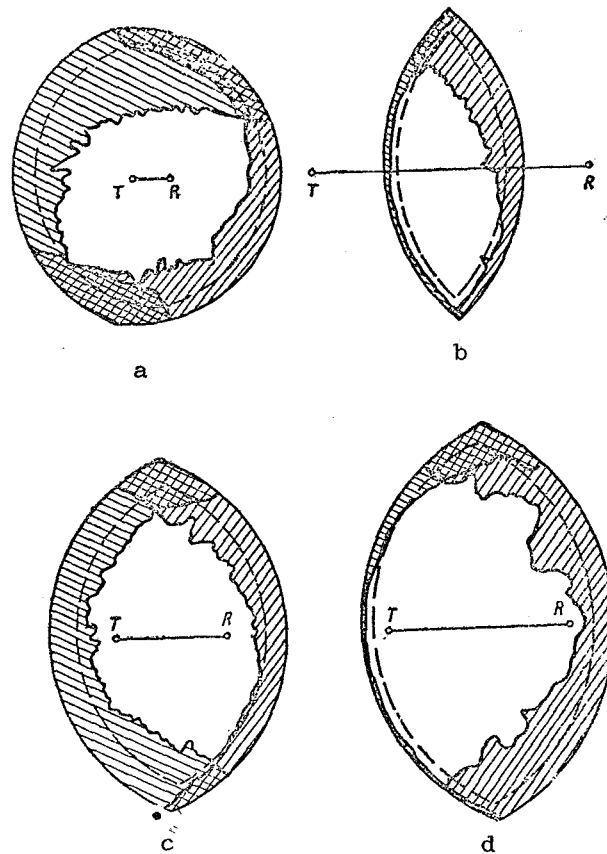


Figure 5. Mountain shadow relief in the permissible region:
a - path No. 1; b - path No. 4; c - path No. 2; d - path No. 3.

2° increments. These provided mountain heights, H , with the largest angles of elevation, Θ , and their distances, L , to a designated point on the path. Knowing H and L , we found angle Θ by using the equation

$$\text{ctg}(\sigma n - \Theta) = \frac{(R+H)\sin\alpha}{(R+h_n) - (R+H)\cos\alpha}, \quad (4)$$

where

$$\alpha = \frac{180 \cdot L}{\pi R}, \quad (5)$$

R is the radius of the earth (Figure 5). Then, using

$$\sin \rho_n = \frac{r_n \cdot \cos(\sigma_n - \Theta)}{R + h} \quad (6)$$

where

$$r_n = (R + h_n) \sin(\sigma_n - \Theta) + \sqrt{(R + h)^2 - (R + h_n)^2 \cos^2(\sigma_n - \Theta)} \quad (7)$$

and

h is the mean height of the reflection points in the meteor zone, angles ρ_n ($n = T, R$) were obtained for each azimuth ψ_n .

Then the mountain shadow relief was constructed for each path, using the coordinates $\psi_n \rho_n$ for a calculated shadow point and a stereographic grid [11]. The area between the relief and the limits of the permissible region is hatched. The crosshatching shows the shadow areas. That part of the relief designated by the dashed line was obtained from insufficient data because necessary topographic maps were unavailable (Figure 5 a, b, c, d).

The results of measurements of the shadow areas, S_{shad} , in relative units, and the S_{shad}/S calculation in %, are listed in the table.

As will be seen from the table (columns 12 and 13), the areas of the permissible regions shadowed by mountains are quite extensive for all four paths.

Mountains obviously will offer particularly great interference on paths close to the limit in length.

Conclusions

1. There is a definite increase in the region permissible for meteor radio wave propagation over mountain paths, the end points of which are at some height above the surface of the earth.

2. The presence of mountain barriers along the path of meteor radio propagation leads to attenuation of part of the permissible region fringe, reducing the area of the permissible region. The reduction is greater the higher the mountains, or the closer they are to the end points of the path.

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Mountains have an especially large interference affect on paths with lengths close to the limit, and this must be taken into consideration when planning the corresponding lines for meteor radio communication in mountainous terrain.

REFERENCE

1. Kalinina, N. N., "A Graphical Method for Determining the Geometric Parameters of Meteor Propagation of Radio Waves," Sb.: Meteornoye rasprostraneniye radiovoln [Collection: Meteor Propagation of Radio Waves], No. 3-4, KGU Press, Kazan', 1966.